JNIF

Java Native Instrumentation Framework

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Introduction

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- Dynamic program analysis is one the main approaches, generally based on instrumentation, i.e.
  - The ability to add or change instructions to a target program in order to observe a desired property.

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- JVMTI agents are written in native code (usually C or C++).
- Instrumentation using JVMTI are more accurate because it can control the entire JVM, catching all event in the bootstrap phase.
- But usually requires an external process to implement the instrumentation itself.

Use Custom ClassLoader

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- Some applications already use a custom classloader for their purposes.

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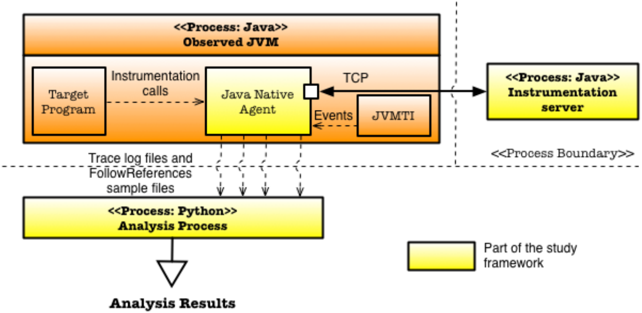
  - Special attention to avoid instrumenting the instrumentation itself.
- Activates after the JDK have been loaded
  - Unable to instrument JDK

Java Native Agent

Java Native Agent implemented with JVMTI API.

- Ask the instrumentation server to instrument all classes in the JVM.
- Hooks on every event of interest
    - Class creation
    - Instrumentation calls

Motivation: External process



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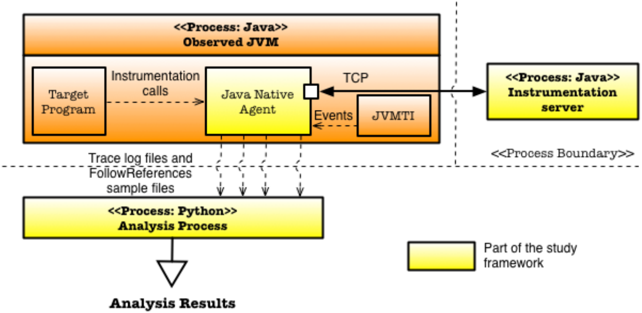

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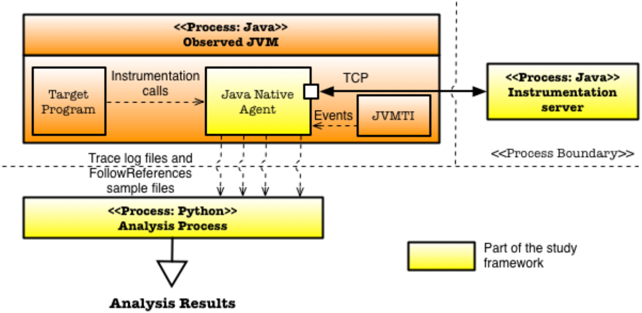

- A Java Native Agent attached to the observed program.
- An Instrumentation Server for bytecode instrumentation.

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- C++ library/framework that allows instrumentation and analysis of Java bytecode.

JNIF

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- Ability to parse and write java class files.
- Object model to query every item in a class file.
- Stack map frames generation.
    - Control flow graph representation.
    - Data flow equation to type check every method.
- Parse and write returns the original bytecode (nothing get change): Important property to make test cases.

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  - Class loading issues.
  - The class path must be replicated in the instrumentation server in order to search for the common super class.

JNIF: Reading a class file

```
const char* data = ...;
int len = ...;

jnif::ClassFile cf(data, len);
```

JNIF: Reading & Writing

```
const char* data = ...;
int len = ...;
jnif::ClassFile cf(data, len); // Parse buffer

// Analyze or edit the ClassFile ...

// Encode the ClassFile into binary
int newlen = cf.computeSize();
u1* newdata = new u1[newlen];
cf.write(newdata, newlen);

// Use newdata and newlen ...

delete [] newdata; // Free the new binary
```

JNIF: Traversing methods

```
const char* data = ...;
int len = ...;
jnif::ClassFile cf(data, len);

for (jnif::Method* m : cf.methods) {
  cout << "Method:␣";
  cout << cf.getUtf8(m->nameIndex);
  cout << cf.getUtf8(m->descIndex);
  cout << endl;
}
```

JNIF: Instrumenting constructor

```
ConstIndex mid = cf.addMethodRef(classIndex,
    "alloc", "(Ljava/lang/Object;)V");

for (Method* method : cf.methods) {
  if (method->isInit()) {
    InstList& instList = method->instList();

    Inst* p = *instList.begin();
    instList.addZero(OPCODE_aload_0, p);
    instList.addInvoke(OPCODE_invokestatic, mid,p);
  }
}
```

```
InputStream is;
if (args.length == 0) {
    is = new FileInputStream("");
} else {
    is = new ByteArrayInputStream(null);
}
// What is the type of is at this point?
```

Evaluation

- Dacapo benchmarks to evaluate performance
- Compare compute frames in JNIF and ASM
- In-process JNIF vs out-of-process ASM
- Metrics
  - Overhead in instrumentation time
  - Parser, writer, compute frames
  - Total running time

ASM Instrumentation server

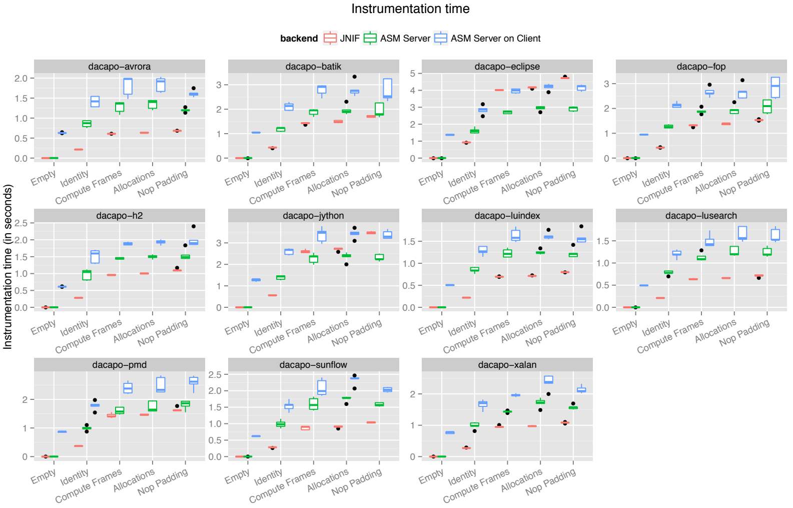
Main Goal

Instrument every class that is requested

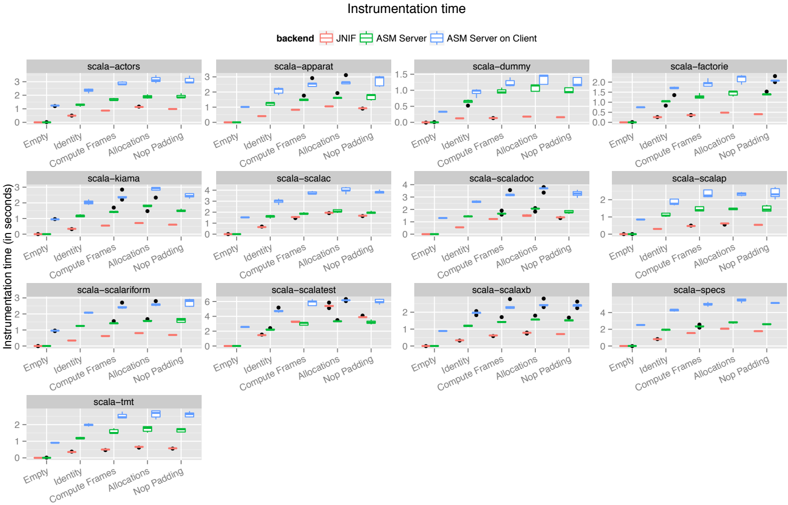
- Receives instrumentation TCP requests with class file bytecodes.
- Uses ASM [1] for instrumenting the class files.
- Responses with instrumented class files.
- The instrumented class files invokes native methods on a predefined class that are implemented by the Java Native Agent.

[1] http://asm.ow2.org/

Evaluation: DaCapo Instrumentation time



Evaluation: Scalabench Instrumentation time



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  - Initial successful tests with JRuby.

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- Partial support for invokedynamic
  - Initial successful tests with JRuby.
- Improve data-flow algorithm
  - Issues when bytecode has several exception handler entries.

Thanks!

Suggestions/Questions/Feedback